Hay Creek Stream Rehabilitation Project – Roseau Minnesota

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Design Overview

The Hay Creek Section 206 project attempts to bring Hay Creek and adjacent lands to a more natural hydrologic condition. There are two components to this project – Hay Creek and the Norland area – in which aquatic environment will be created, restored, and/or rehabilitated. Figure 1 shows the general layout of the project features.

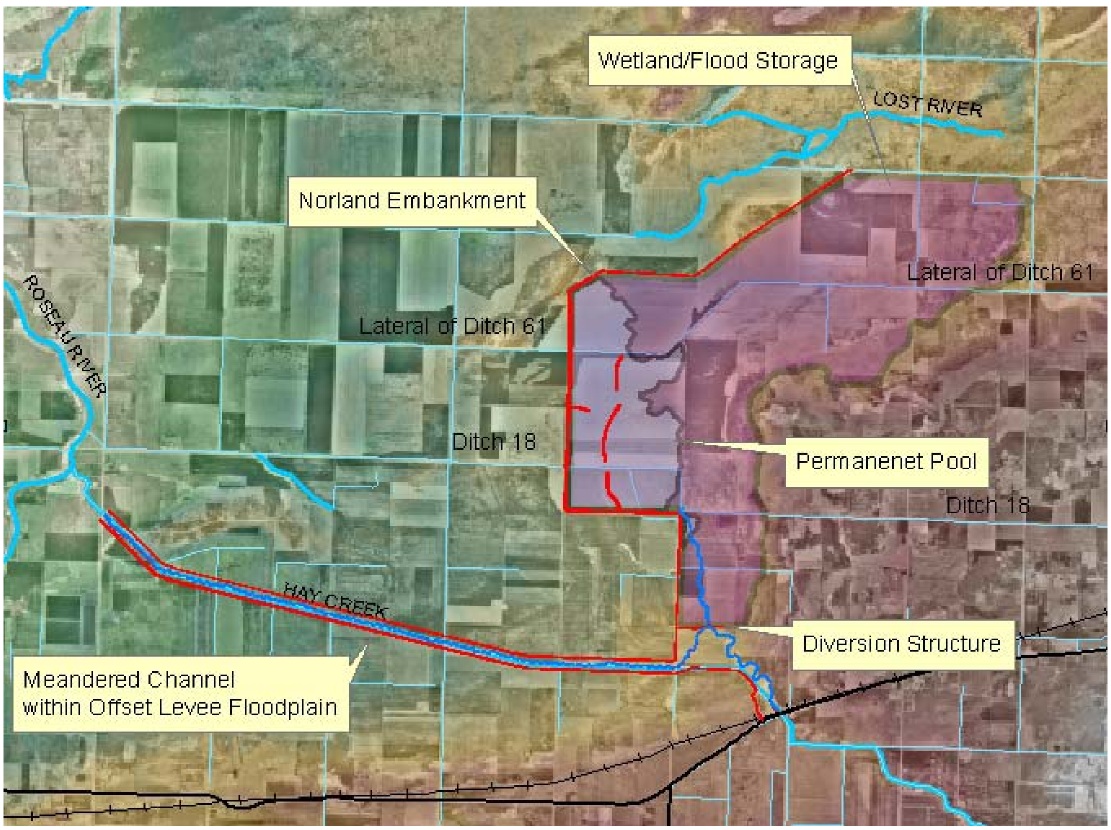

Figure 1. Project Overview

Within the proposed project area, Hay Creek currently flows through a straight, excavated drainage ditch (County Ditch (CD) 7). The project, as envisioned, will divert a portion of higher flows from Hay Creek north into the Norland wetland restoration/floodwater retention site. Hay Creek will carry low flows and a substantial portion of high flows downstream from the Hay Creek-to-Norland diversion to the creek's confluence with the Roseau River via a newly created sinuous channel and artificial floodplain. Norland will also receive inflow from its own 42-square-mile drainage area.

Under current conditions, flooding from Hay Creek can inundate a large area of predominantly agricultural lands as spring and summer floods spread out over the swampy lacustrine plain left after Glacial Lake Agassiz drained about 10,000 years ago. The proposed project will provide similar features within the Norland wetland. Floods from spring snowmelt and summer thunderstorms will inundate the Norland site's marsh and prairie areas.

The project's sinuous Hay Creek channel will provide varied habitats during low-flow periods, and a 500-foot-wide floodplain defined by setback levees will provide conveyance for floodwaters that are not diverted into the Norland site. The re-meandered Hay Creek channel will receive naturally shaped hydrographs.

CD 18 and the Lateral of Judicial Ditch (JD) 61 both enter the Norland site from the east. The proposed project will intercept the base flows from these ditches and direct them to supplement Hay Creek discharges when possible.

Original Hay Creek Flow Path

At this time, it is not certain exactly where the course of the natural original Hay Creek was located. However, topographic information, old mapping and aerial photos have been used to identify the likely flow paths. Hay Creek originally entered the lacustrine plain of the current project area from the southeast. The grade became very flat as it passed the location of present-day Highway 11. The channel shifted periodically across the glacial lakebed. Figure 2 shows two of the main flow paths of the original Hay Creek. The purple line shows one of the main flow paths identifiable from aerial photographs.

The creek apparently meandered to the north joining with Lost River, which eventually merged with the lower end of Sprague Creek before entering the Roseau River. Some reaches of the original creek alignment are particularly difficult to trace, e.g., as it passes through the northwest section in the Norland area. It may have spread out through marshlands leaving little evidence. It is also likely that large floods would spill out of this watercourse and follow alternate routes westward to the Roseau River. The blue-green alignment in Figure 2 is another flow path identified on aerial photos. There is also some evidence from old mapping that this may have been the primary channel when this area's drainage ditches were constructed many years ago.

Figure 2. Evidence of Old Hay Creek (and other) flow paths

Hay Creek Corridor

Several alternative corridors for the rehabilitated Hay Creek were considered. One candidate was restoring the northern (to Lost River) alignment. This would divert flow from Hay Creek, CD 18, and Lateral of JD 61 into an adjacent basin (Lost River) and increase the probability of flooding in the latter. However, shifting flood problems from one area to another would be an untenable solution. Therefore, efforts focused on retaining flows within the existing basins of Hay Creek, CD 18, and Lateral of JD 61.

Another corridor alignment was considered which did not follow the original Hay Creek alignment. Possible old breakout channels from the original Hay Creek and other swales were linked to provide a corridor where the floodplain would be more naturally integrated with the new stream. The blue-green line on Figure 2 shows this alignment. Landowners along this corridor were not interested in providing the required land; therefore, this alternative was abandoned.

Other alternatives basically followed the existing Hay Creek (CD 7) corridor, but introducing a more meandering corridor alignment in place of the existing straight one. Consultation was made with the non-Federal sponsor and other stakeholders, such as State and Federal agencies, landowners, and environmental organizations. The consensus was to follow the existing straight-segment alignment of CD 7 with a 500-foot-wide floodplain defined by setback levees, within which a sinuous low-flow channel would be constructed.

This adopted corridor never contained a natural stream. The land is generally flat, but with a gentle slope to the north with undulations. Consideration was made as to what character the new floodplain adjacent to the meandering channel would have: It could be regraded to provide a gentle slope toward the new channel … or more-or-less retained in its current form. The latter alternative was chosen because it would provide additional habitat diversity as itemized below:

a. Preservation of the topsoil. Minimizing disturbance to the topsoil will be beneficial to the quality of future plant life in the corridor.
b. The unevenness of the floodplain will create intermittent ponding areas that fill after flooding but will not naturally drain. This will occur typically to the north of the channel due to the general slope of the land, but may also occur on occasion to the south. Floodplain velocities are not expected to significantly exceed 1 foot per second even for large flood events. Therefore, there should not be much danger of erosion to the inside toes of the setback levees.

Hay Creek Diversion Structure

The Hay Creek diversion structure will control the amount of flow passing between Hay Creek and the Norland wetland restoration/floodwater retention site. The structure consists of a weir and a culvert. The culvert allows a modest outflow to Norland during small-to-moderate runoff events, and the weir allows larger amounts of water to leave Hay Creek during large floods. This will ensure that naturally shaped hydrographs will pass through the Hay Creek's new sinuous channel for most flow conditions. The culvert also controls flow back into Hay Creek from Norland after the creek's high stages subside. The culvert will also allow excess flows from CD 18 and the Lateral of JD 61 to utilize Hay Creek should there be a major runoff event in the Norland watershed that is not mirrored in the Hay Creek drainage area.

The Hay Creek diversion structure would have a 3-foot x 6-foot box culvert with an invert elevation of 1050.8. Only a 3-foot x 3-foot opening is necessary for the project. The 3-foot x 6-foot box culvert is a more standard size, less expensive, and allows some flexibility for the future if additional capacity is deemed appropriate. A 3-foot width of this 3-foot x 6-foot culvert will be left open during all project operation scenarios. Stoplogs will block the rest of the culvert. The additional culvert area may be utilized for diverting Hay Creek through Norland during excavation/construction of the Hay Creek reaches downstream of the diversion structure. The structure has a 1,500-foot-long weir at elevation 1057.5, likely in the form of a road crest.

Interrelationship between Hay Creek Diversion Structure, Hay Creek Sinuous Channel Corridor, and Norland Permanent Pool

The diversion structure, meandering Hay Creek channel, and conservation pool elevation in Norland are all functionally interrelated:

a. The diversion structure culvert must be higher than the Hay Creek normal flow stages to prevent diversion of Hay Creek low-flows into Norland, and to prevent sedimentation problems in the culvert and connecting channel.
b. The conservation/permanent pool in the Norland area must be high enough to back excess baseflow from the Norland watershed into Hay Creek during the latter's low-flow conditions.

The design of the Hay Creek channel influences the diversion of flow through the structure. The backwater stages of Hay Creek at the structure are influenced by downstream channel and floodplain geometry as well as seasonal changes in vegetation in Hay Creek's floodplain corridor. These stages affect the amount of water diverted north into the Norland site during runoff events.

Hay Creek Sinuous Channel Design

The goals of the stream restoration/rehabilitation are to produce a stream that will function geomorphologically as a natural stream and provide habitat qualities optimal to fish and wildlife.

Channel Forming Discharge

Much of the design will be related to the channel forming discharge of Hay Creek, the flow rate that is most critical to defining channel geometry in a natural stream. Generally, this discharge is around the 1.5- to 2-year flow. The 2-year discharge has been chosen for this project. The 2-year discharge was adopted because of the uncertainty of the discharge frequency relationship of Hay Creek. It was deemed better to be too high than too low because designing with too low a channel forming discharge would produce a slightly undersized channel with a tendency toward more erosion of the newly dug channel, whereas using slightly too high a channel forming discharge would produce a trend towards deposition on the banks of the channel. The eventual dynamic equilibrium of the channel should be reached more quickly by choosing a slightly larger channel forming discharge.

Three Reaches

The design of Hay Creek was done using the concept of a channel forming discharge. It was necessary to break Hay Creek into three reaches:

Reach A – Last bend in corridor (west) to County Road 28
Reach B – From the diversion structure to the last bend in the existing CD 7 alignment upstream of County Road 28
Reach C – Highway 11 downstream to the diversion structure

Reaches A and C are transition reaches joining Reach B to existing channel dimensions at the project's upper and lower limits. The design of Reach B will be discussed because it is the primary stream restoration feature and that design is dictated primarily by the slope of the 500-foot-wide floodplain corridor.

Reach B

Reach B extends from the diversion structure downstream to the large corridor bend upstream of County Road 28. Near the upper end of this reach the floodplain will be very wide. A meandering channel will be cut through existing agricultural fields from the diversion structure to the 500-foot-wide corridor that is the dominant feature of Reach B.

The Stable Channel Dimensions utility of the SAM – Hydraulic Design Package for Channels (developed by the Corps of Engineers - Waterways Experiment Station) was used to determine stable channel dimensions. The model uses the sediment transport and resistance equations developed by Brownlie. The draft "User's Manual for the SAM Hydraulic Design Package for Channels" (March 18, 1998) introduced this procedure as follows:

> "This analytical approach determines dependent design variables of width, slope, and depth from the independent variables of discharge, sediment inflow and bed material composition. It involves the solution of flow resistance and sediment transport equations, leaving one dependent variable optional. Minimum stream power is used as a third equation for an optional unique solution. This method is based on a typical trapezoidal cross section and assumes steady uniform flow. The method is especially applicable to small streams because it accounts for transporting the bed material sediment discharge in the water above the bed, not the banks, and because it separates total hydraulic roughness into bed and bank components."

For the 2-year discharge of 250 cfs, about 80 cfs of the peak is conveyed north into the Norland area. The design channel forming discharge below the diversion structure is 170 cfs. The floodplain slope of the corridor is 0.0005 ft/ft. Side slopes of 1-vertical-on-3-horizontal were deemed the steepest slope that could be used without inviting problems with geotechnical instability.

Figure 3 shows the results from SAM for Reach B. Each of the lines is related to a different discharge condition, and identifies the range of bottom width and energy grade line slopes where stable channel dimensions are expected. The 170-cfs discharge is the adopted channel forming discharge in this reach.

SAM also identifies the "minimum stream power" channel bottom width of 40 feet with a water depth of 2.8 feet. The minimum stream power dimensions are often considered optimal for channel stability. This was not acceptable because this channel would have very shallow water depths during low-flow periods, which would not be seen as optimal habitat. In addition, this shallow depth would make the transition to meet existing channel inverts in Reaches A and C much more severe.

Instead, a bottom width of 8 feet was adopted for this reach. The graph indicates that this channel should be stable for a wide range of discharges. The SAM program estimates that at the channel forming discharge the water depth will be 5.0 feet deep. This depth will establish the channel bottom elevation as referenced from the natural ground elevation. The invert of Reach B will be above the invert elevation of existing CD 7; so Reach A will have to provide a steeper transition at the downstream end of the project, and Reach C will require a shallower slope upstream.

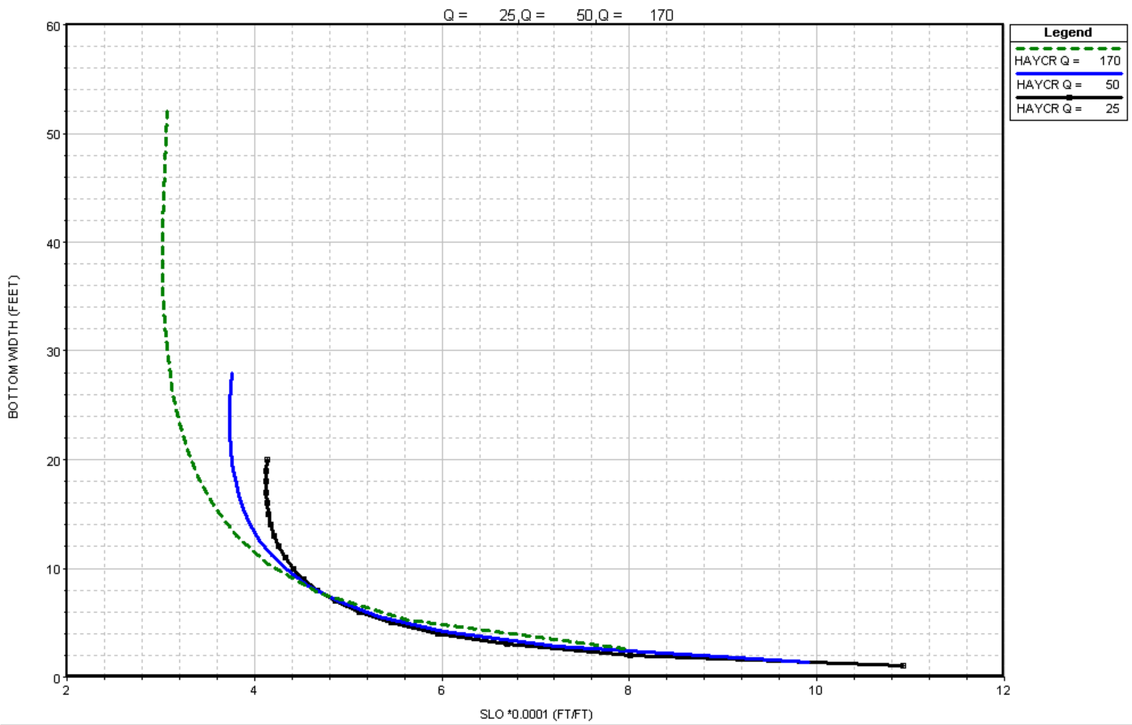

Figure 3. Stable Channel Curves from SAM – Reach B

Meander Patterns

The establishment of a new and hopefully naturalistic meander pattern is a goal of this project. Natural streams have a wide variety of variability in pattern, which provides diverse habitat conditions. A reference reach was used to provide a naturalistic meandering planform for Hay Creek.

Use of Sprague Creek as Reference Reach

The use of a reference reach is helpful for constructing a channel design that will be in tune with the geology and geomorphology of this region. This was particularly true when choosing stream characteristics for creating the sinuous channel for Hay Creek because it was impossible to use historical topographic or other clues since Hay Creek did not originally flow through this corridor.

Sprague Creek is an appropriate candidate for a reference reach. The Sprague Creek basin is only about 5 miles north of Hay Creek. The geologic features of the floodplain are very similar to those underlying the Hay Creek corridor. Although Sprague Creek has also gone through many alterations over the years due to channel modifications and levees, its central reach may still represent its original planform or at least something very close to it. Cohesive soils of the area make planform adjustment a slow process. And an inspection by a Corps biologist indicated favorable aquatic habitat conditions occur within this reach. It has a sinuosity of 1.2, and a slope of about 0.00053 feet/feet through the adopted reach shown (, which is very similar to that of the proposed Hay Creek layout).

An HEC-2 hydraulics model from a previous study was available for Sprague Creek. This was converted to the HEC-RAS format. The 2-year discharge for Sprague Creek was run in the model and produced a water surface profile that looked reasonable at various Sprague Creek cross sections, some of which were bankfull, others of which were more entrenched and showed the water surface at or near in-channel bench locations.

Development of Hay Creek Planform

The planform of the new Hay Creek was based on the planform of Sprague Creek. EM 1110-2-1418 states that:

> "Meander plan dimensions are more or less proportional to the width of the river. On maps and aerial photographs, large and small rivers appear generally similar, so that the appearance of a stream gives no clue as to scale of a map."

Segments of the middle reach of Sprague Creek that showed a regular meandering character were chosen. These stream segments were digitized and then spliced together. Mirror images of these digital alignments were then made about a vertical axis and then about a horizontal axis. This produced four patterns with the meandering character of the Sprague Creek segments. The ratio of regime equation channel widths for Sprague Creek (width = 48 ft) and Hay Creek channel widths (width = 27 ft) produced a scale factor of 0.56. This factor was applied to the four similar planform patterns. These patterns were then copied and aligned within the 500-foot-wide Hay Creek floodplain corridor. A 75-foot buffer was left between the new sinuous channel and the setback levees to eliminate much of the concern of channel migration endangering the levees. Figure 3 shows the proposed Hay Creek channel planform.

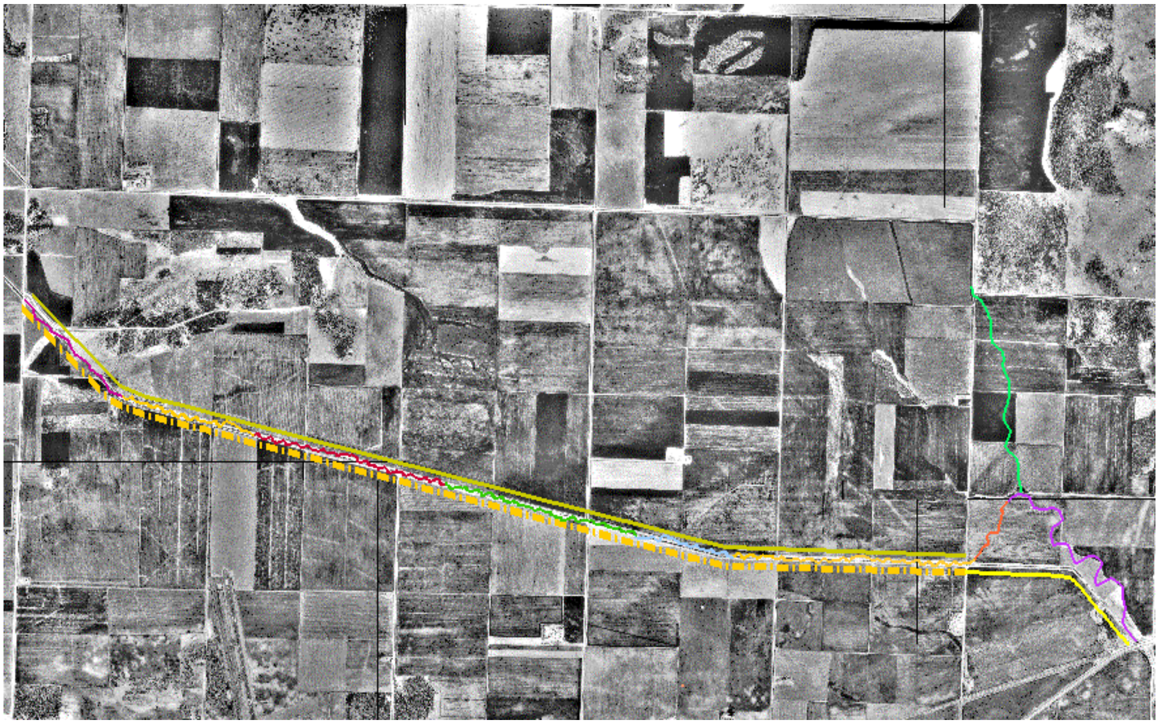

Figure 3. Hay Creek Sinuous Channels

Riffle Areas and Enhanced Pool Areas Along Hay Creek

Ideally, the channel could be excavated with a lot of variation in channel dimensions such as greater depths on the outside of bends, etc. This was not done for this project primarily in an effort to keep design and construction costs down. The relatively small dimensions of the channel and its significant length would make construction of detailed features difficult and time consuming. It is expected that natural processes over time will reshape some of the features. To supplement those long-term developments, some riffle sections and deeper enhanced pool areas will be constructed at various locations.

Rock riffles placed at various locations along the new Hay Creek planform will add habitat diversity and help maintain deeper water depths during low-flow conditions. Each riffle will be constructed of coarse gravel- to cobble-size rock and will extend about 25 feet along the channel.

Several areas of excavation will be done along the new Hay Creek to produce deeper pool areas termed 'enhanced pool' areas. This cross section will extend for 30 feet with two 20-foot transitions on each end.

Currently, 24 riffles and 20 enhanced pool areas are proposed and their locations can be seen in the design drawings. These features will be significantly submerged during flood conditions and should not impact the general channel design. Additional riffles and enhanced pool sections could be added to the design if the additional cost is acceptable.

Flood Maps

The following Figure 4 shows the estimated effects of the project on flooding for the 25-Year Summer Flood. This is one of a series of similar figures produced for the study. On the figure dark blue shows areas that will flood for both existing and project conditions. Light blue signifies areas that have increased stages. These are namely in the Norland area and along the Hay Creek Corridor. Green shows areas that the modeling indicates existing condition flooding that is eliminated by the project.

The mapping only shows areas believed to be flooded by Hay Creek, Ditch 18 and the Lateral of Ditch 61. Additional local drainage will provide additional flooded areas than those shown on the mapping. In addition, local drainage may increase the extent of ponding attributed to Hay Creek, CD18, and L.JD61. An example of this may be seen to the south of the Hay Creek alignment. Drainage from the south may increase the ponding shown in the maps.

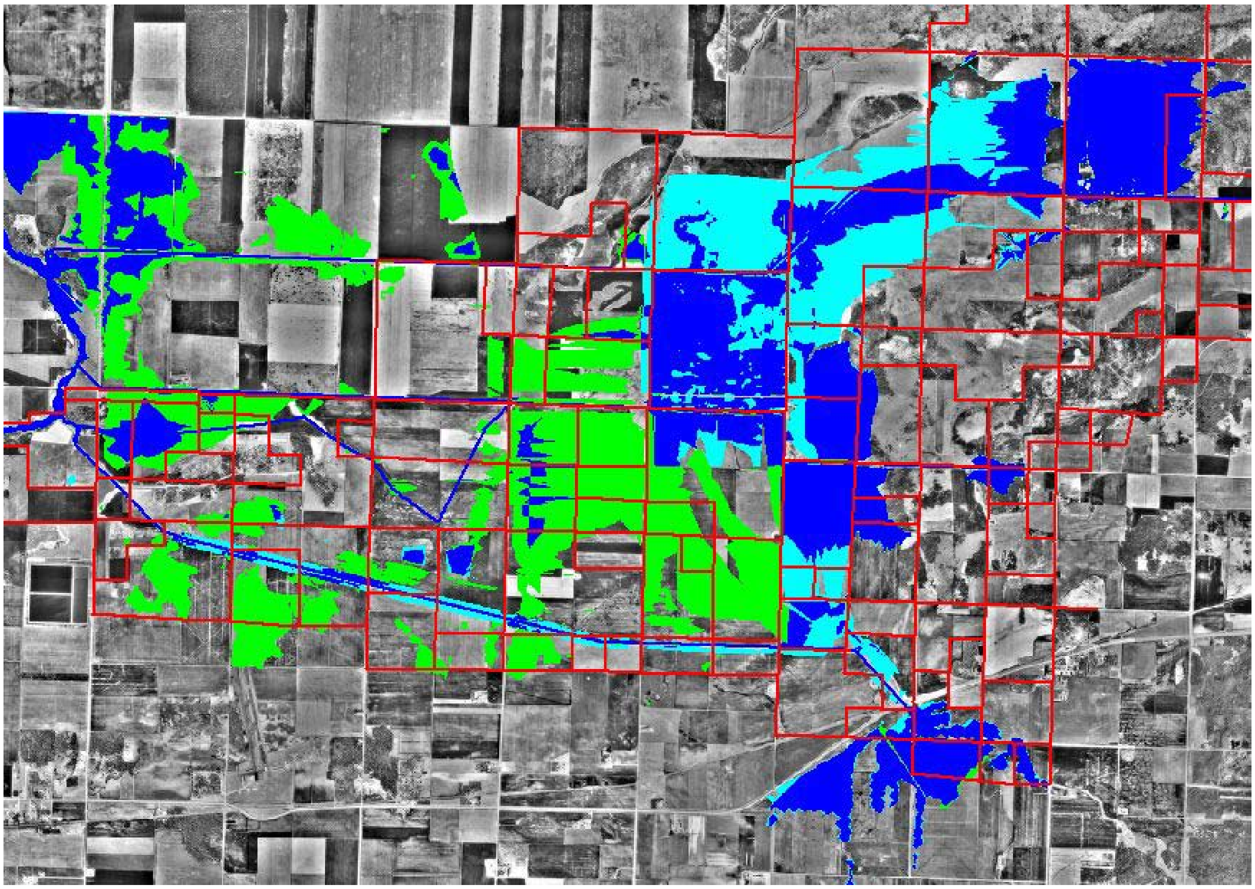

Figure 4. Change in flooding pattern – 25-year summer flood

Dark Blue – Flooded under existing conditions /flooded with the project
Light Blue – Not flooded under existing conditions / flooded with the project
Green – Flooded under existing conditions / not flooded with the project